Tree-livestock interaction promotes nutrient shift and influences plant species richness in orchards

Schmiedgen A.[1], Schmitz A.[1], López-Sánchez A.[2,3], Roig S.[2,3] and Isselstein J[1]
[1]*Institute of Grassland Science, Georg-August University, 37075 Goettingen, Germany;* [2]*ECOGESFOR. Ecology and Sustainable Forest Management Research Group and Department of Natural Systems and Resources. Technical University of Madrid. Ciudad Universitaria, s/n 28040 Madrid, Spain;* *anja.schmitz@agr.uni-goettingen.de*

Abstract

Orchards are traditional but endangered agroforestry landscape elements in the continental part of Europe and of high importance for nature conservation. Trees introduce diversity into grasslands, as they establish microsites with different conditions through modification of light availability and soil chemical parameters. In orchards, livestock may promote distinct nutrient deposition as they tend to rest and defecate under trees, which might affect plant species composition and richness. In 42 orchards within the Rhenish Uplands (Germany) we studied how different grazer species (cattle, horses and sheep) affect soil nutrient accumulation (P_2O_5 and K_2O) in microsites along a tree-proximity-gradient (under the crown, ecotone, non-tree affected area) and how this influences plant species richness in microsite habitats and at paddock scale. Our results show higher amounts of K_2O and P_2O_5 and fewer numbers of species under the crown compared to the ecotone and non-tree affected area. Further, we found differences in plant species richness at the paddock scale among different grazer species with higher diversity on horse compared to cattle and sheep grazed pastures. Increasing grazing intensity promoted K_2O deposition and decreased species richness at microsite and paddock scale.

Keywords: nutrient deposition, grazer species

Introduction

In the Continental European landscapes, orchards are traditional but endangered agroforestry elements with high nature conservation value. Usually, they experienced no history of agricultural improvement and they therefore display relatively high plant species richness. Furthermore, trees introduce diversity into grasslands, as they increase the richness of niches with considerable variation in light availability and soil chemical parameters, enabling coexistence of species with different requirements at the microscale (Garbarino and Bergmeier, 2014). Despite grazing animals differ in their grazing impact, they are known to enhance grasslands dynamics, diversity and species richness at all scales by selectivity, trampling and nutrient deposition (Ollf and Ritchie, 1998, Rigueiro-Rodríguez *et al.,* 2009). Therefore, grazers may enhance tree-dependent spatial heterogeneity due to nutrient deposition as they tend to rest and defecate under trees in orchards (Wilson *et al.,* 2007). Soil nutrient concentration in general has been shown to affect plant species richness and composition (Janssens, 1998) but there is a lack of research on the combined effect of grazing induced nutrient shift and plant species richness in orchards. Therefore, in this study we test the hypotheses that in orchards grazer species differ in their impact on (1) heterogeneity in soil nutrient concentration of microsites, (2) species richness of microsites and (3) species richness at paddock scale, and that these effects also depend upon grazing intensity.

Materials and methods

In 2014 we studied a total of 42 grazed orchards within the Rhenish uplands in Germany. Sites were arranged in a nested triplet design, comparing horses, cattle and sheep grazing at similar site conditions (altitude, soil and slope). Within each site 3 trees were chosen randomly and at each tree 3 microsites (1 m^2) were arranged under the crown ('trunk'), in the ecotone and in an area that was not tree-affected

('open'). Soil samples (500 ml) were collected at a depth of 10 cm, pooled for microsite categories respectively and analysed for plant available phosphorus (P_2O_5) and potassium (K_2O). All plant species per microsite were identified to determine species richness (SR) at microsite. SR at paddock scale was defined as cumulative number of species found in the nine microsites. Data on site-management were recorded interviewing farmers using standardized questionnaires. As a variable for grazing intensity, live weight-unit (500 kg) grazing days per year were calculated for each site and standardized per hectare. Statistics were performed in R 3.2.2 (R Development Core Team 2008). Linear Mixed Effects Models (lme) were applied to analyse the effects of microsites, grazer species and grazing intensity on soil pH, P_2O_5, K_2O and species richness at micro scale and paddock scale using nlme package. SR at paddock scale was tested for effects of grazer species and grazing intensity. In all models tree nested within site and, this, nested within triplet was considered as a random effects structure. Minimal adequate models were assessed performing stepwise backward selection with χ^2-test and significant parameters were estimated by Maximum Likelihood Estimation. Assumptions were tested graphically.

Results and discussion

We found significant differences in soil chemical parameters between microsites indicating tree and grazing induced nutrient deposition within paddock. Concentrations of P_2O_5 and K_2O showed lower values with increasing distance to the tree (Figures 1A, B) which is consistent with findings of Wilson *et al.* (2007). Hypothesis 1 is confirmed, as a significant interaction of microsite with grazer species was obtained.

Close to the trunk the concentrations of P_2O_5 were significantly higher in cattle than in horse or sheep grazed paddocks (P<0.001) and K_2O concentrations were significantly higher in cattle and sheep compared to horse paddocks (P<0.001). Further, the concentration of K_2O is significantly (P=0.049) modified by grazing intensity. Generally, horses are known to establish distinct latrine areas where they urinate and defecate and introduce distinct heterogeneity in grasslands swards and nutrient deposition (Schmitz and Isselstein, 2013; Wrage *et al.,* 2011) whereas cattle and sheep tend to drop their excreta more homogenously (Ollf and Ritchie, 1989). In orchards, nutrient deposition seems to differ in this

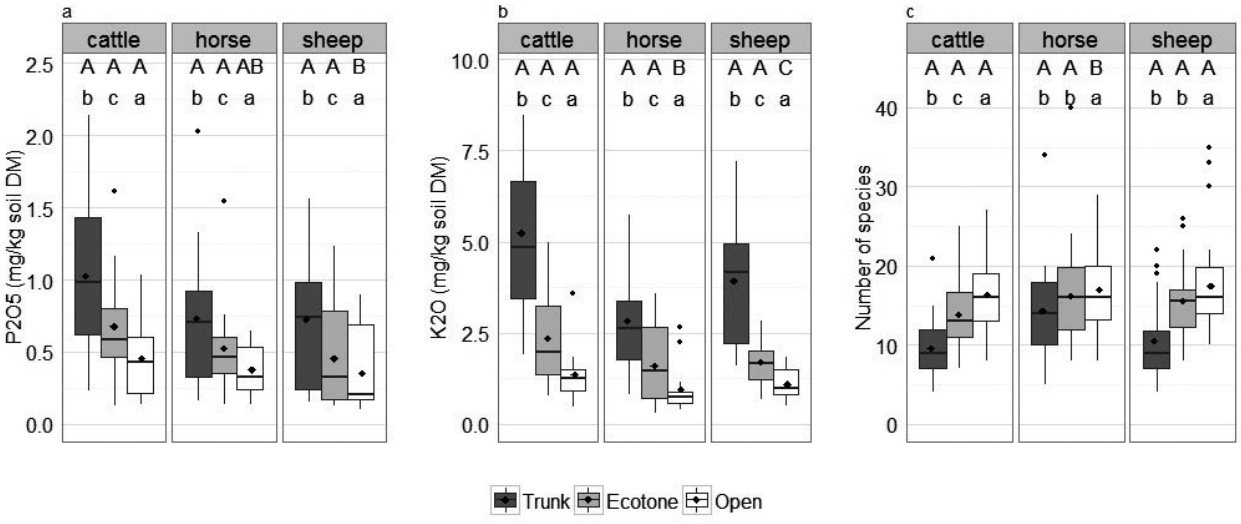

Figure 1. Allocation of nutrients (A) P_2O_5, (B) K_2O and (C) species richness at the microsites 'Trunk', 'Ecotone' and 'Open' of cattle, horse and sheep paddocks. Interactions of microsite and grazer species were significant for P_2O_5 (P<0.001), K_2O (P<0.001) and SR (P<0.001). Significant differences among grazer species within microsites are represented by upper case letters and of microsites within grazer species by lower case letters. Dots within the bars represent mean values. DM = dry matter.

respect. Horse latrine areas are not necessarily depending on the presence of trees while cattle use the shady tree areas for resting and obviously also for defecation and urination.

In general, the number of plant species increased significantly with increasing distance to the tree and decreasing nutrient concentration (Figure 1C). Yet, this effect was modified by the grazer species as SR of the trunk area was significantly highest on the horse paddocks while there was no difference among the grazer species in the ecotone and open microsite. This is in accordance with hypothesis 2. Janssens *et al.* (1998) showed distinct negative effects of P_2O_5 concentrations on species richness which is in line with our data of P_2O_5 concentration and number of species at the microsites. On paddock scale SR was significantly affected by grazer species ($P<0.001$), with slightly higher SR in horse grazed pastures, but also significantly modified by grazing intensity ($P<0.001$).

Conclusions

In orchards plant species richness is affected by nutrient deposition, grazer species and grazing intensity. Horse grazed pastures showed slightly higher species richness than cattle or sheep grazed orchards. Therefore, concerning conservation of plant species richness in orchards, in absence of sheep or cattle, horses should also be reconsidered as grazer species for nature conservation strategies.

Acknowledgements

The study was financed by following PhD fellowships: German Federal Environmental Foundation (DBU) (A. Schmitz); and Spanish Ministry of Education, Culture and Sport, and Consejo Social of Universidad Politécnica de Madrid (A. López-Sánchez). We thank all participating landowners as well as Biostation Oberberg and Biostation Rhein-Sieg.

References

Garbarino M. and Bergmeier E. (2014) Plant and vegetation diversity in European wood-pastures. In: Hartel T, Plieninger T (eds.) European Wood-pastures in Transition. Routledge, New York, pp. 113-131.

Herzog, F. (1998). Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe. *Agroforestry Systems* 42, 61-80.

Janssens, F., Peeters, A., Tallowin, J.R.B., Bakker, J.P., Bekker, R.M., Fillat, F. and Oomes, M. J. M. (1998). Relationship between soil chemical factors and grassland diversity. *Plant and Soil* 202(1), 69-78.

Olff, H. and Ritchie, M.E. (1998). Effects of herbivores on grassland plant diversity. *Trends in Ecology & Evolution* 13(7), 261-265.

Rigueiro-Rodríguez, A., Fernández-Núñez, E., González-Hernández, P., McAdam, J.H. and Mosquera-Losada, M.R. (2009). *Agroforestry in Europe*. Springer Netherlands.

Schmitz, A. and Isselstein, J. (2013). Effects of management on vegetation structure in horse pastures. In: The role of grasslands in a green future. *Grassland Science in Europe* 18, 394-396.

Wilson B.R., Growns, I. and Lemon, J. (2007). Scattered native trees and soil patterns in grazing land on the Northern Tablelands of New South Wales, Australia. *Australian Journal of Soil Research*, 45, 199-205.

Wrage, N., Strodthoff, J., Cuchillo, H. M., Isselstein, J. and Kayser, M. (2011). Phytodiversity of temperate permanent grasslands: ecosystem services for agriculture and livestock management for diversity conservation. *Biodiversity and Conservation* 20(14), 3317-3339.